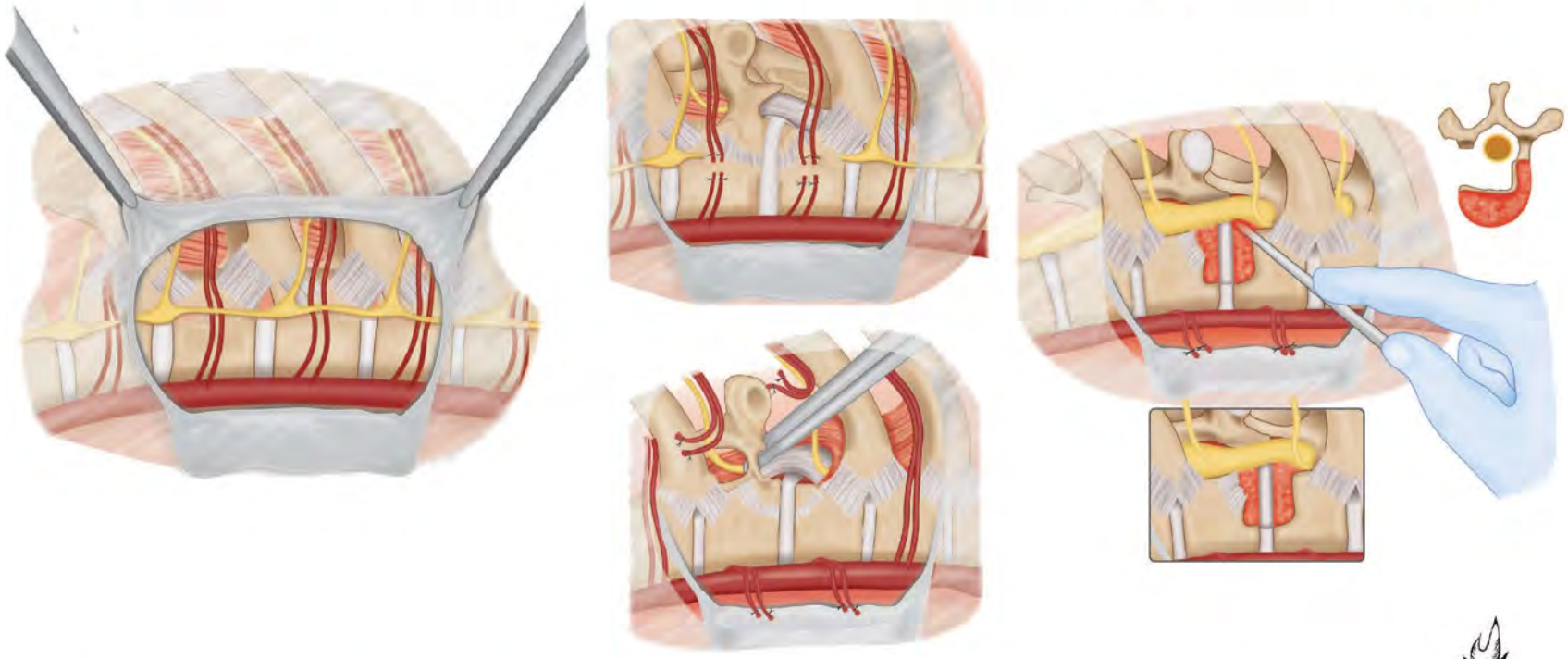
Spine Surgery

Expert Techniques in SPINE Surgery



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Arjun Sebastian

Foreword
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JAYPEE

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CHAPTER

3

Cervical Total Disc Arthroplasty

Hannah Kirby, Patrick Morrissey, Nelson Saldua

ANATOMY

The cervical spine is comprised of seven vertebra with fibrocartilaginous intervertebral discs situated between each segment from C2 to C7. These discs are comprised of a tough outer covering of radially oriented collagen fibers known as the annulus fibrosus which surrounds the softer nucleus pulposus comprised mainly of water and a loose collagen fiber network. The annulus fibrosus is intertwined with both the anterior and posterior longitudinal ligament, which serve as the dorsal and ventral borders of the intervertebral space. The lateral borders of this space are defined by the uncinate processes, which extend from the lateral aspect of the superior endplates, creating a cup-like shape and articulating with the inferolateral border of the superior vertebral body. These articulations are called the uncovertebral joints. The sagittal depths of the cervical vertebral bodies average approximately 14 mm, but variability does exist and should be kept in mind during decompression.[1]

Lateral to the uncovertebral joints are the transverse foramen anteriorly and the lateral masses more posteriorly. The mean distance from the medial aspect of the uncovertebral joint to the medial aspect of the transverse foramen has been reported as 5.4 mm on the right side of all normal vertebrae and 5.7 mm on the left.[2] The vertebral artery typically travels within this foramen, with the average distance between the uncinate process and medial border of the vertebral artery being only 2 mm.[3] One must appreciate this important relationship during decompression, taking care not to venture lateral to the uncinate process which could result in an iatrogenic vertebral artery injury.

The neural foramen at each level is bordered superiorly and inferiorly by the pedicles of the adjacent vertebral bodies, anteromedially by the uncovertebral joints, and posterolaterally by the facet joints. There are eight cervical nerve roots, with each root exiting the spinal canal though the neural foramen above its corresponding numbered pedicle, with the exception of the C8 root, which exits above T1.

Other important neural structures are the sympathetic plexus and the recurrent laryngeal nerves. The sympathetic plexus lies on top of the longus colli muscle, which sits ventral to the vertebral column. The plexus can be damaged with poor retractor placement or excessive retraction. The recurrent laryngeal nerves run on either side of the trachea in the tracheoesophageal groove. There is more constant anatomy of the recurrent laryngeal nerve on the left side as it loops under the arch of the aorta, making this side the preferred approach for anterior cervical spine surgery[4] although nerve injury rates have been shown to be similar for both left and right side approaches.

SURGICAL INDICATIONS

In general, the indications for total cervical disc arthroplasty (CDA) are similar to anterior cervial decompression and fusion (ACDF). Any patient with anterior pathology and near normal segmental motion can be a candidate for CDA after they have failed an appropriate course of nonoperative treatment to include activity modification, physical therapy, nonsteroidal anti-inflammatory drugs, and possibly selective nerve root blocks.

Cervical disc arthroplasty candidates should have normal cervical spinal alignment and mobility along with either radiculopathy or myelopathy caused by a

disc herniation or foraminal osteophytes.[5-7] The Food and Drug Administration (FDA) has approved CDA for both one- and two-level applications (implant specific) with several prospective studies demonstrating equivalent and in some cases superior results compared with traditional ACDF.

Contraindications to CDA include more than three vertebral levels requiring treatment, instability (translation > 3 mm and/or >11° rotational difference to that of either adjacent level), known allergy to implant materials, posttraumatic vertebral body deficiency or deformity, facet joint degeneration, significant deformity, bridging osteophytes, disc height loss more than 50%, and absence of motion (<2°). Other contraindications include osteoporosis/osteopenia, prior surgery at the level to be treated, active malignancy, systemic disease [acquired immunodeficiency syndrome (AIDS), human immunodeficiency virus (HIV), hepatitis B or C, and insulin-dependent diabetes], other metabolic bone disease, renal failure, Paget's disease, rheumatoid arthritis, morbid obesity, pregnancy, active or prior cervical infection, and chronic corticosteroid use.[6,7]

Many patients who are candidates for ACDF are candidates for CDA. A retrospective review of 167 consecutive patients who underwent elective cervical spine surgery found that 43% of patients would be candidates for CDA and that this amount increased to 47% if treatment of adjacent-level degeneration was included.

SURGICAL TECHNIQUE

Prior to proceeding to the operating room, every patient indicated for a CDA should also be consented for the possibility of changing the plan to an ACDF. This is important because there are several intraoperative challenges that can preclude safe and effective implantation, the most important of these being radiographic visualization. As we will show later, clear C-arm images of the complete intervertebral space are required for accurate device implantation. This can be difficult at the lower cervical levels, particularly C6-7. While these levels may be clearly imaged in upright office radiographs, they will often be difficult to see intraoperatively despite optimal patient positioning. If unable to obtain adequate imaging during the procedure, the surgeon should abort the CDA in favor of an ACDF, which does not require detailed fluoroscopic imaging.

Anesthetic considerations are identical to those in ACDF with mean arterial pressures maintained above 85 mm Hg for all patients with a diagnosis of myelopathy. As with all cervical spine surgery, routine neuromonitoring is strongly recommended with both motor and sensory evoked potentials obtained throughout the procedure.

Patient positioning in the operating room is paramount to the success of CDA. The patient should be positioned supine on a radiolucent table in order to allow for both anteroposterior (AP) and lateral fluoroscopic imaging. Arms should be appropriately padded with gel rolls or foam and tucked at the side using a draw sheet while ensuring thumbs are pointed up. The shoulders should be taped down and secured to the bed with 3-inch silk tape, making sure the force vector is aimed toward the patient's feet. This serves to both stabilize the patient and improve sagittal visualization, allowing the more caudal levels to be clearly seen on fluoroscopy. The neck should be positioned in neutral rotation and with neutral lordosis. The authors suggest using an inflatable intravenous (IV) pressure bag placed in the interscapular region to allow for fine adjustments of sagittal alignment during the procedure should they be necessary. You may also choose to secure the head to the table by taping the chin or forehead to prevent intraoperative rotation.

The skin incision should be made according to standard palpable landmarks. The hyoid bone is typically at C3, thyroid cartilage is at C4-5, and the cricoid cartilage is at C6. The skin incision should extend from just across midline to the medial border of the sternocleidomastoid. The approach is carried out in a manner similar to ACDF. The platysma is incised in line with the skin incision and a subplatysmal flap is developed bluntly. The interval between the sternocleidomastoid laterally and the strap muscles medially is identified and bluntly dissected with scissors. Occasionally, when operating on caudal cervical levels, the omohyoid muscle can preclude adequate exposure. Should this be the case, the muscle can be divided at its medial aspect with electrocautery, with no repair required at the conclusion of the procedure. The carotid sheath is identified by palpating the pulse and the entire sheath and its contents should be maintained laterally. The pretracheal fascia is divided within this interval, exposing the prevertebral fascia overlying the longus colli musculature and the cervical spine. The prevertebral space is bluntly cleared with gentle finger sweeps both cranially and caudally and the prevertebral fascia is divided longitudinally. The vertebral bodies and intervertebral discs are easily identifiable with the overlying longus colli and anterior longitudinal ligament (ALL). The appropriate cervical level is identified with a lateral radiograph.

Once the appropriate level has been identified, the longus colli musculature is elevated to expose the disc space from uncus to uncus. A cranial and caudal dissection should expose at least the midpoint of the vertebral bodies above and below the operative level. Self-retaining radiolucent retractors are then placed under the elevated longus colli, being careful to avoid damaging the cervical sympathetic chain that overlies these muscles. It is important to minimize soft tissue trauma during this step to decrease the possibility of postoperative heterotopic ossification.

Once the operative level is exposed, Caspar pins are placed in the cranial and caudal vertebral bodies. The pin placement is extremely important and should be performed under fluoroscopic guidance. In the coronal plane, the pins should be placed perfectly midline. In the sagittal plane, they should be placed parallel to the endplates and at least 5 mm from the disc space to facilitate decompression and instrumentation (Fig. 3.1). A Caspar pin distractor is then placed to facilitate decompression and device implantation.

The decompression is performed with several important considerations. A thorough discectomy is required, removing all disc material and endplate cartilage; however, unlike the decompression in ACDF, particular attention is paid to preservation of the bony endplate structure. Maintaining the natural dome of the inferior endplate of the cranial vertebra and the symmetric upslope of the uncus on the superior endplate of the caudal vertebra will assist with device fit and segmental stability. If possible, small anterior osteophytes and bony overhang should be preserved. Following discectomy, the posterior longitudinal ligament is symmetrically released and decompression of the canal and foramen is carried out with the use of a Kerrison rongeur. The posterior uncinate process may be taken as part of the decompression, but the remainder should be left intact anteriorly.

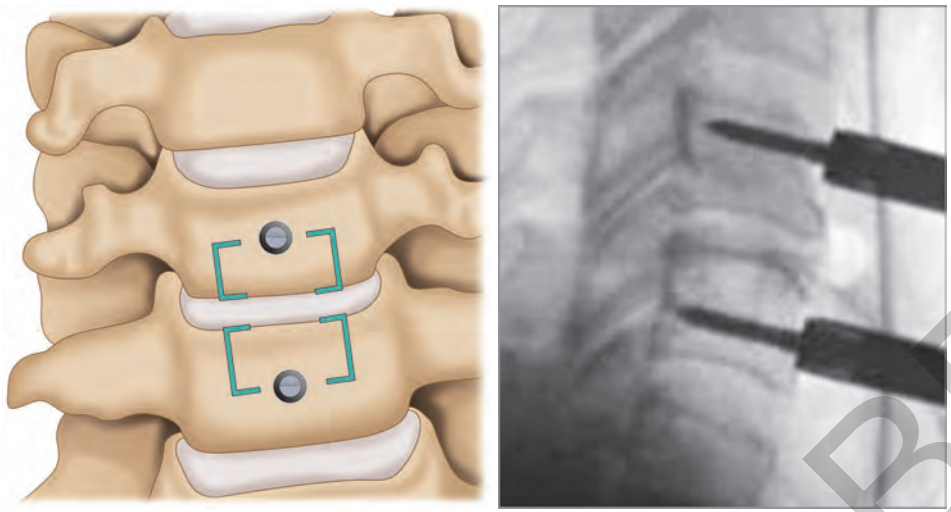


Fig. 3.1: Caspar pins should be placed in the center of the vertebral body on AP imaging (left) and parallel to the operative endplates (right), ensuring at least 5 mm of working distance from either endplate (AP: anteroposterior).

Once the decompression is complete, width and depth measurements are taken as per the manufacturer's recommended technique. The appropriately sized trial components are then placed under fluoroscopic guidance. Start the insertion with lateral fluoroscopy, ensuring that implant trajectory is in line with the disc space. Gently tap the trial into place, stopping once it is centered in the disc space. Release the Caspar pin distraction and assess trial size by comparing the operative disc height to the levels above and below, being careful not to overstuff the disc space. At this point, one should also confirm that the trial is appropriately centered on AP fluoroscopy.

Once satisfied with trial placement, reapply Caspar pin distraction and remove the trial. Assemble the device on the insertion handle as per the manufacturer's instruction and prepare for final implant placement. Again, insertion is performed under fluoroscopic guidance ensuring that the implant is in line with the disc space on the lateral radiograph. In addition to this radiographic check, also ensure that the insertion handle is perpendicular to the operating room table when viewed from the patient's feet to account for appropriate medial/lateral trajectory. Gently insert the implant according to the specific manufacturer's instructions. An ideally placed implant will fill the anterior-posterior diameter on the lateral radiograph and will be centered on the AP image (Fig. 3.2). If the implant is slightly smaller than the disc space on the lateral, ensure it is centered from front to back as opposed to being flush with the posterior aspect of the vertebral body. Once satisfied with implant position, remove distraction and take final fluoroscopic images.

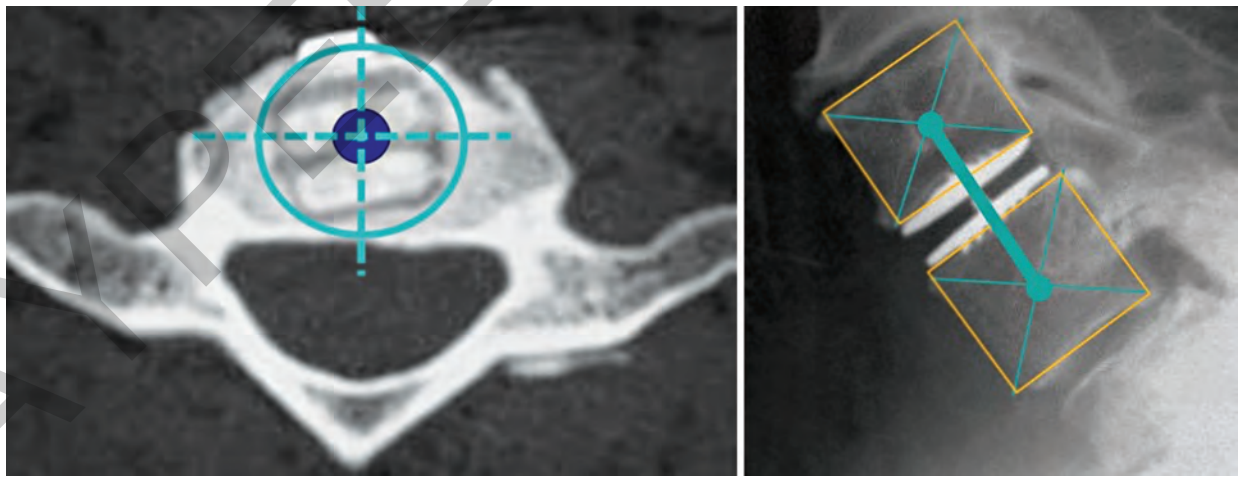


Fig. 3.2: Ideal implant positioning should be centered within the vertebral body. This is confirmed on AP and lateral fluoroscopy prior to conclusion of the case (AP: anteroposterior).

Careful attention is paid to ensure complete hemostasis, including the use of bone wax in Caspar pin tracts. A retropharyngeal drain often recommended overnight to lessen the likelihood of a postoperative hematoma. The platysmal and dermal layers are both closed with an absorbable braided suture and a monofilament suture is used for the skin. A postoperative cervical collar is not required, although a soft collar may be used initially for patient comfort for 1–2 weeks.

OUTCOMES

The widespread use of cervical total disc arthroplasty started with the BRYAN® Cervical Disc (Medtronic) in 2000. Many designs have followed, but the longest outcome data is on the Bryan prosthesis. The theoretical advantage of CDA is to maintain motion, with the hopes to avoid symptomatic adjacent segment disease which has been described as occurring at a rate of 2.9% per year.[8]

Sasso et al.[9] described 7–10 year follow-up for CDA, with the BRYAN® Cervical Disc (Medtronic), versus ACDF in a single-center randomized prospective trial. At 7 and 10 years of follow-up, both groups improved and maintained the improvement in comparison to their preoperative neck disability index (NDI) and Visual Analog Scale (VAS) neck/arm baseline scores. The NDI was significantly better for the CDA group versus the ACDF group at both time points; 8.6 and 21 at the 7-year follow-up and 8 and 15 at the 10-year follow-up, respectively ($p = 0.0138$ and $p = 0.0485$). At the 7-year follow-up, the VAS neck and arm scores were also significantly different favoring CDA but became statistically insignificant at 10 years. At 10 years, the CDA group demonstrated a trend toward less reoperation due to adjacent segment disease as compared to the ACDF group. Two patients (9%) of the CDA group required operative interventions (one patient at an adjacent level and a second patient at a nonadjacent level), and eight patients (32%) of the ACDF group required reoperation (six at adjacent levels and two patients at nonadjacent levels). Overall surgical survivorship of the CDA group was 90.90 versus 68.0% in the ACDF group, but this difference was not significant.[9]

A recent meta-analysis of randomized controlled trials with a minimum of 2-year follow-up showed a significant different in reoperation rate of 6% (108 of 1,762) in the CDA group and 12% (171 of 1,472) in the ACDF group.[10] While this meta-analysis showed a significantly higher revision rate in the ACDF cohort, the authors caution interpretation of these results given the limited follow-up and heterogeneity of studies included. At this time, while CDA has been established as a safe alternative to ACDF in select patient populations, additional studies are needed to determine efficacy of one technique over the other.

COMPLICATIONS

Complications of anterior cervical spinal surgery can be divided into intraoperative, early, and late. The intraoperative risks of CDA are similar to ACDF with intraoperative complications including injuries to the esophagus, vertebral artery, and recurrent laryngeal nerve. Dural tears and spinal cord or nerve root injuries are also possible.[11] These adverse events can occur for various reasons including inappropriate retractor placement, inadvertent intraoperative trauma, poor preoperative planning, excessive lateral discectomy, and patient positioning.

All of these complications are rare, but can have devastating consequences. Esophageal injury has been reported in 0.2–0.4%[12-14] and can have mortality rates approaching 20% even when identified early. The incidence of vertebral artery injury was found to be 0.3% in a review of 1,976 patients undergoing anterior cervical surgery,[15] also with a high rate of additional systemic complications. The incidence of dural tear during anterior cervical spine surgery has been reported at 1–3.7%[16] with a study analyzing 1,223 anterior spinal surgery cases showing a rate of 1%.[17] Spinal cord injury has an incidence of 0.2–0.9%[13,16,18] with the risk minimized by the widespread implementation of intraoperative neuromonitoring.

Early and late postoperative complications include reintubation, dysphagia, dysphonia from recurrent laryngeal nerve injury, Horner's syndrome, and retropharyngeal hematoma requiring evacuation (1%).[19,20] Airway compromise, which can occur secondary to soft tissue edema, retropharyngeal hematoma, or airway reactivity is a life-threatening complication and should be immediately addressed by reintubation and then appropriate medical or surgical interventions. The prevalence of reintubation from all causes was 0.1% in a multicenter retrospective cohort of 8,887 patients undergoing anterior cervical spine surgery.[21]

The incidence of dysphagia varies widely from 28% to 57%[22-24] and is mostly self-limited with prolonged moderate to severe dysphagia reported in 1.3–4% of patients.[20,22] The incidence of dysphonia also varies in the literature, but most cases of recurrent laryngeal nerve injury recover with time. A persistent symptomatic vocal fold paresis ranges from 0.33 to 2.5%.[25,26]

For all of the complications above, both CDA and ACDF have similar risk profiles with no significant differences between the procedures.[19,20] However, there are unique complications for cervical total disc arthroplasty including implant malposition, heterotopic ossification, osteolysis, intraoperative prosthesis migration (1%), and overmilling of the vertebral body (1%) leading to implant subsidence.[20]

One group investigating the complications associated with the BRYAN® Cervical Disc (Medtronic) analyzed 96 disc arthroplasties in 74 patients. The perioperative complication rate was 6.2% per treated level. In one patient (1%) a retropharyngeal hematoma developed, requiring evacuation. Neurological worsening occurred in three patients. Intraoperative migration of the prosthesis was observed in one two-level case (1%), whereas delayed migration occurred in one patient with postoperative segmental kyphosis (1%). In another patient with severe postoperative segmental kyphosis, revision was required with a customized lordotic prosthesis. Heterotopic ossification and spontaneous fusion occurred in two cases (2%).[20] Several case reports of vertebral body osteolysis and fractured or dislocated implants have also been described, and while the consequences of such failure are potentially catastrophic, these events are fortunately very rare.[27,28]

CASE PRESENTATION

A 31-year-old female was involved in a motor vehicle accident with subsequent right arm pain that did not respond to 6 weeks of conservative treatment including physical therapy, anti-inflammatory medications, and injections. The examination demonstrated normal neck range of motion (ROM) with significant pain, a positive Spurling's sign, and 4/5 strength in the biceps on the right with a slightly decreased deep tendon reflex. She had no long tract findings and no subjective myelopathic complaints. A magnetic resonance imaging (MRI) demonstrated a right-sided disc herniation with compression of the spinal cord and exiting nerve root at C5-6 (Fig. 3.3). Cervical spine radiographs demonstrated preservation of cervical disc height, normal lordosis, and full ROM (Fig. 3.4).

The patient underwent an uncomplicated CDA at C5-6 (Figs. 3.5A to D). Six weeks postoperatively, the patient had complete resolution of arm pain, full strength, and normal neck ROM. 1-year follow-up radiographs demonstrated appropriate implant placement with no evidence of complications and no findings of adjacent segment degeneration (Fig. 3.6).

Case Presentation

Anand Segar, Tyler Kreitz

Cervical Disc Replacement

A 33-year-old female presents with bilateral C6 radiculopathy and weakness in wrist extension and minimal neck pain. She had failed nonoperative management and was adverse to a fusion procedure. Her X-rays showed a well-aligned spine with preserved disc space and minimal facet arthrosis. She was indicated for a C5/6 CDA (Figs. 3.7 to 3.11).

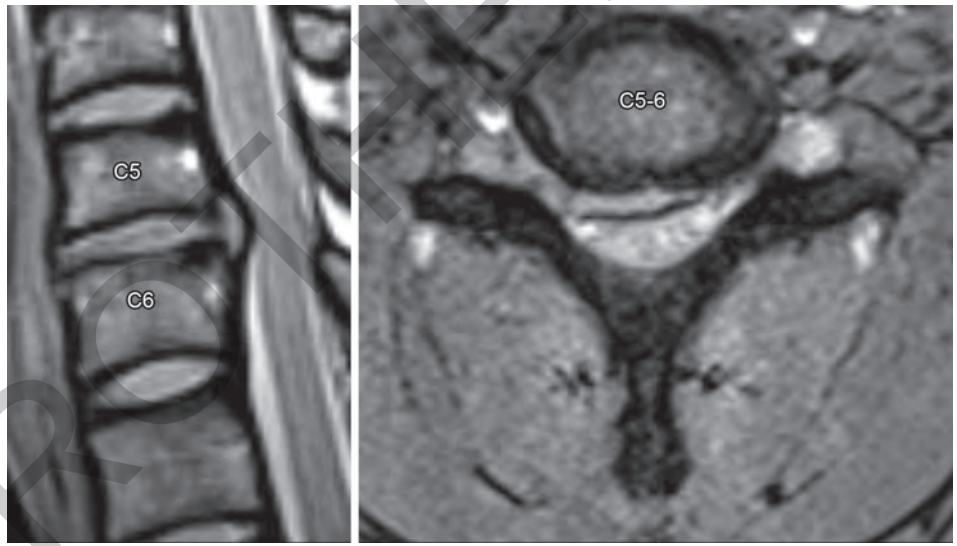


Fig. 3.3: Sagittal (left) and axial (right) MRI demonstrating an acute right-sided disc herniation at C5-6 with compression of both the spinal cord and the exiting nerve root. Overall disc height is maintained relative to the unaffected levels (MRI: magnetic resonance imaging).

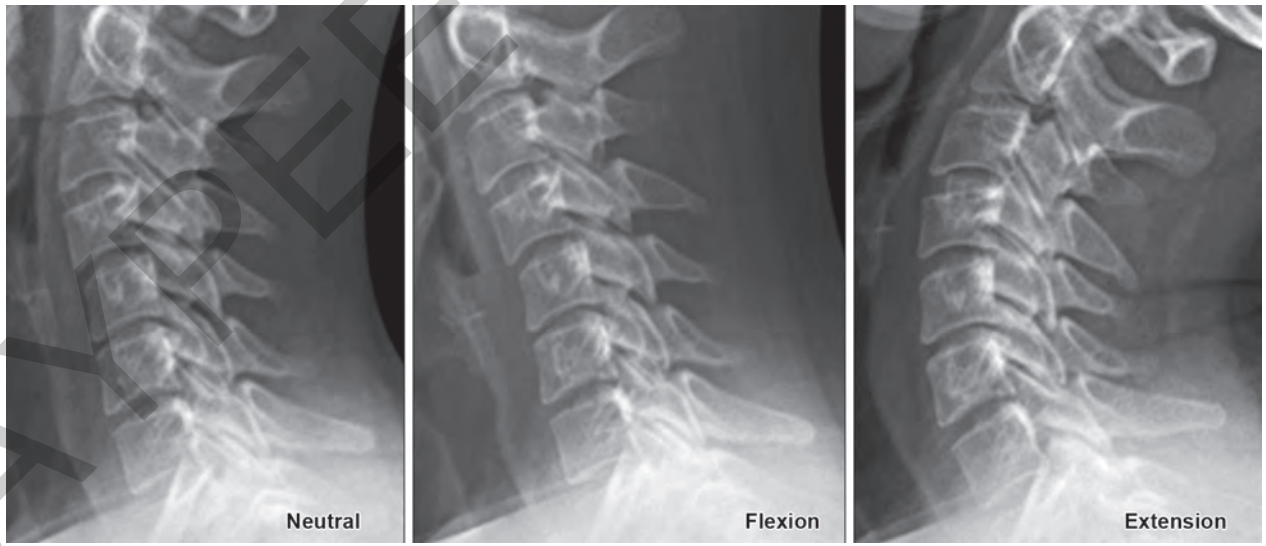
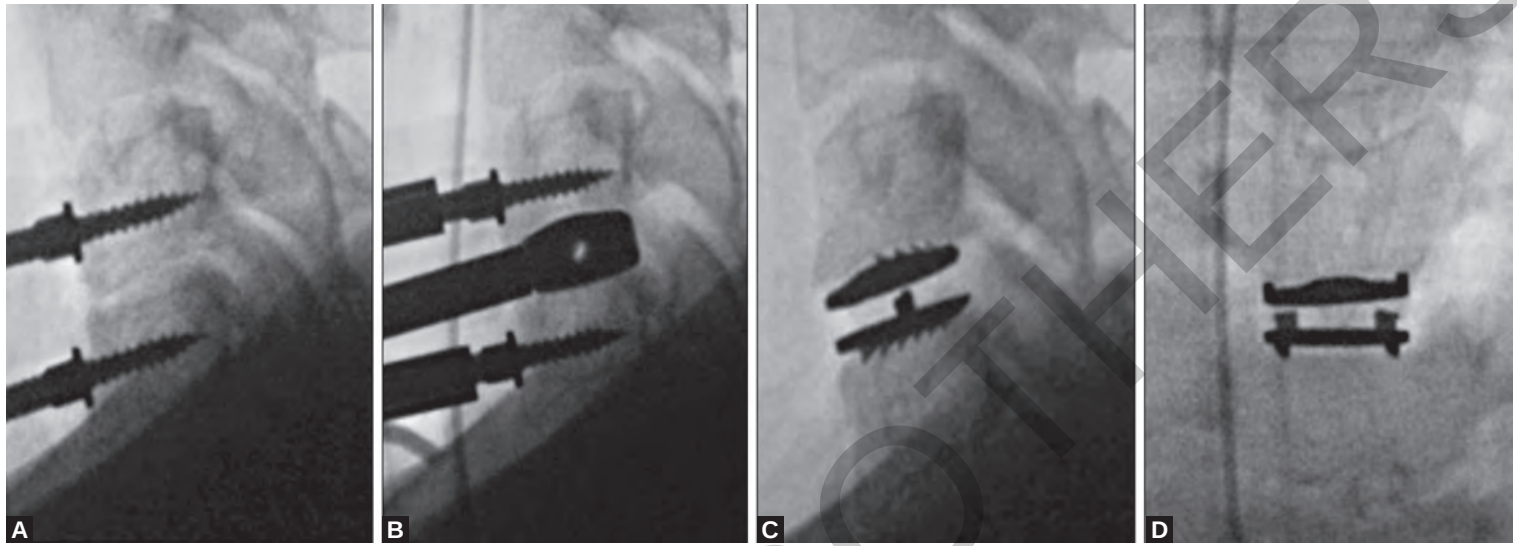


Fig. 3.4: Preoperative lateral cervical spine radiographs demonstrating minimal spondylosis, preservation of lordosis, and normal cervical spinal range of motion.



Figs. 3.5A to D: Intraoperative fluoroscopy demonstrating appropriate parallel Caspar pin placement (A) and trial insertion (B). Final lateral (C) and AP (D) radiographs demonstrate a well-centered implant with an implant height that is similar to the surrounding unaffected disc spaces (AP: anteroposterior).

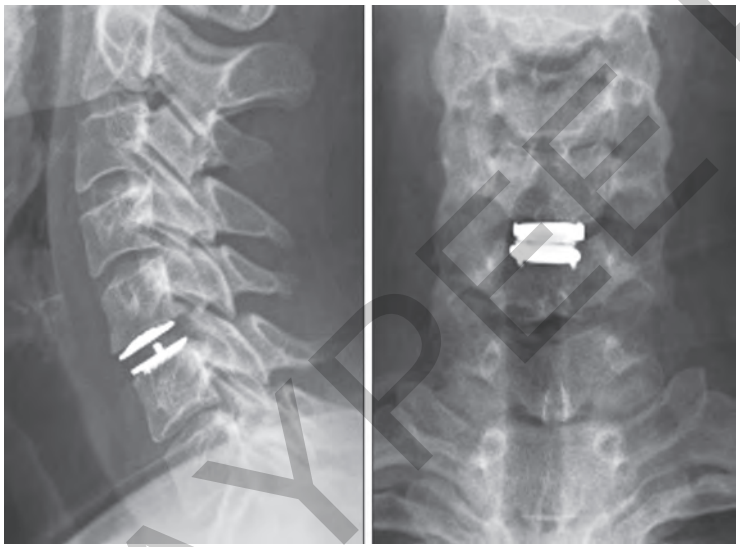


Fig. 3.6: Lateral (left) and AP (right) radiographs obtained at 1-year follow-up. Implant position is appropriately maintained and there is no evidence of adjacent segment degeneration (AP: anteroposterior).

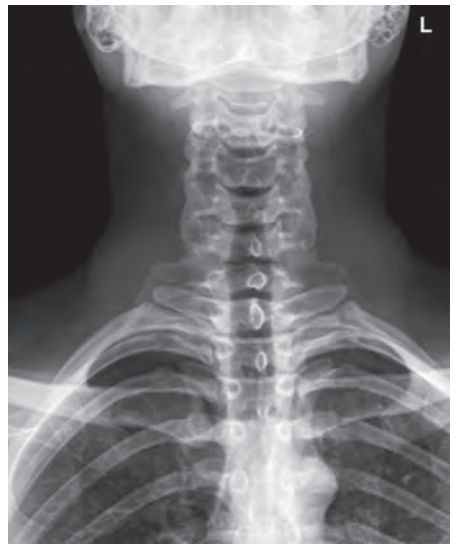


Fig. 3.7: Preoperative AP X-ray showing minimal uncovertebral arthrosis (AP: anteroposterior).

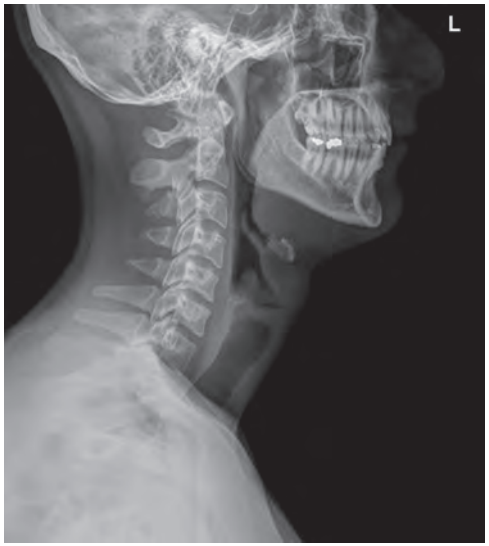


Fig. 3.8: Preoperative lateral X-ray showing minimal facet arthrosis, no listhesis, and preserved disc height.

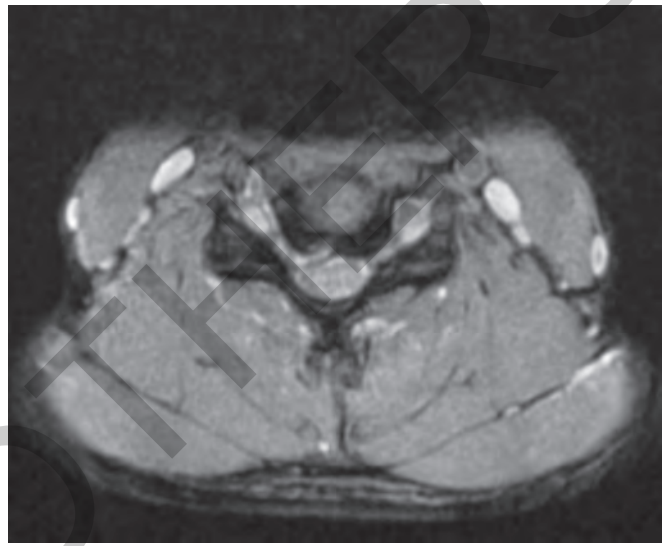


Fig. 3.9: Preoperative axial MR at C5/6 level image showing bilateral foramina stenosis with a right-sided herniated disc (MR: magnetic resonance).

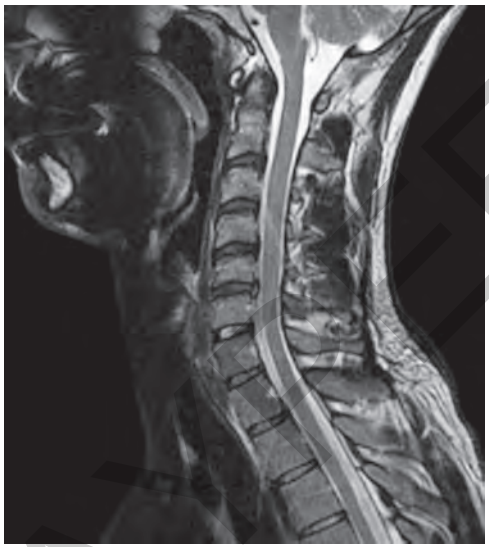


Fig. 3.10: Preoperative sagittal image showing no central stenosis or cord signal change.

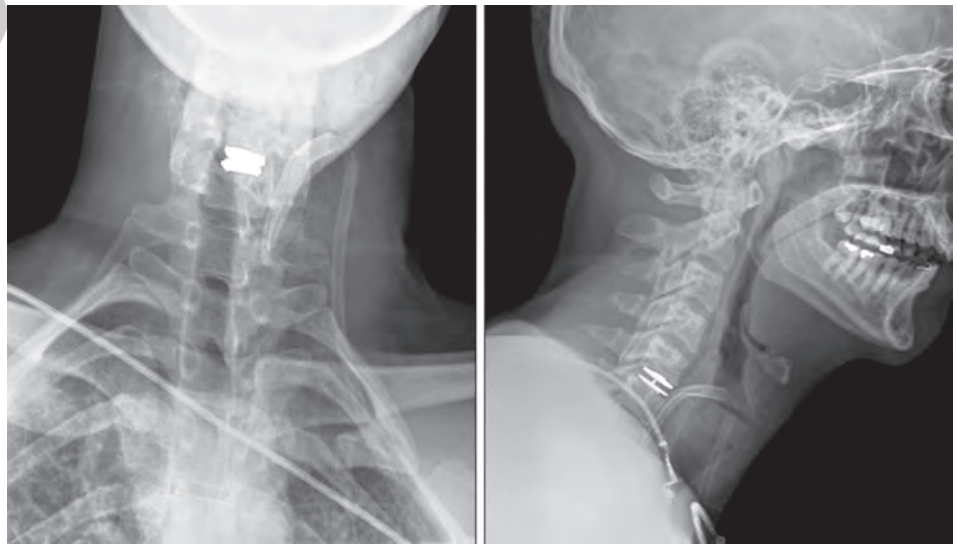


Fig. 3.11: Postoperative AP and lateral image demonstrating an implanted cervical arthroplasty at C5-6 in appropriate alignment.
Courtesy: Dr Alexander R Vaccaro.

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Expert Techniques in SPINE Surgery

Salient Features

- The book is a compendium of complex techniques used in modern day spine surgery
- Covering technically challenging and innovative surgical techniques for the cervical, thoracic and lumbar spine, this text has been carefully crafted as an instructional guide from internationally recognized leaders in the field
- Each of the 12 chapters consists of a methodical outline to breakdown the most complex of contemporary surgical techniques into easy to understand sections for practical application
- From the most current innovations in minimally invasive surgery to more involved multilevel Ponte osteotomies, the text covers a vast array of spinal surgical techniques which are necessary for the effective management of a variety of spinal disorders
- The authors have worked to create a guide that follows a logical, thorough format in dissecting each expert technique with surgical pearls and tips learned over a lifetime by skilled surgeons in the field
- Vast collection of full-color photographs, imaging, and beautifully constructed illustrations for each section
- Case presentations for each technique to simply illustrate complex concepts
- Selection of popular modern surgical techniques, ranging from cervical total disk arthroplasty to pedicle subtraction osteotomy, with tips and pearls from the some of the most recognized innovators in the field
- Both contemporary and thorough in its execution, this book is an essential resource for residents, spine fellows, and attendings in the field who hope to refine their skills and effectively contribute to modern day spine care.

Alexander R Vaccaro MD PhD MBA has graduated Summa Cum Laude from Boston College in 1983 with a BS in Biology. He received his MD degree from Georgetown University School of Medicine where he was promoted with "Distinction". He completed a year of Surgical Internship at Cedars-Sinai Medical Center in Los Angeles, California and his Orthopedic Surgery Residency was at Thomas Jefferson University where he graduated in 1992. Dr Vaccaro completed a Spine Fellowship at the University of San Diego, California. He earned a PhD in 2007 in the field of Spinal Trauma and a MBA in 2015. Dr Vaccaro is the Richard H Rothman Professor and Chairman, Department of Orthopedic Surgery and Professor of Neurosurgery at Thomas Jefferson University in Philadelphia, Pennsylvania, USA. He has over 730 peer reviewed and 200 non-peer reviewed publications. He has published over 340 book chapters and is the editor of over 58 textbooks and co-editor of OKU-Spine I and editor of OKU-8. Dr Vaccaro is the President of Rothman Institute, Chairman of the Department of Orthopedic Surgery, Co-Director of the Regional Spinal Cord Injury Center of the Delaware Valley and Co-Director of Spine Surgery at Thomas Jefferson University Hospital where he instructs current fellows and residents in the diagnosis and treatment of various spinal problems and disorders.

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